Critical Success Factors for a Hospital-wide PACS

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Since 1996 a picture archiving and communications system (PACS) is installed at the university hospital of Freiburg. The PACS is integrated in the hospital information system (HIS) and several modalities of different vendors are attached to it. During the implementation phase three critical factors to the success of our PACS installation where identified: the support of the workflow, the interface of the radiological information system (RIS) to the modalities, and the security policy to allow hospital-wide access to the images and results in the PACS.

INTRODUCTION

Freiburg university hospital is a rather large hospital with more then 1,700 beds, over 50,000 inpatients a year, and about 300,000 outpatient visits per year in the south of Germany.

Starting in 1988 the introduction of a picture archiving and communication system was proposed at the university hospital in Freiburg. Due to changes on the vendor's side, technological changes like the appearance of ATM, and the introduction of the DICOM 3.0 communication standard the project was delayed until 1996 when it was introduced at the department of radiology where it is now used on a routine basis.

From the start of the project it was desired not to have a single vendor PACS but to be able to choose components like different modalities from different vendors. Unfortunately at that time the only interface standard available was the ACR-NEMA standard. The different flavours of the implementations of such an interface made extensive discussions between the communicating partners necessary. The interfaces varied not only from one vendor to another but they also differed from one modality to another even for the same vendor. Since at the department of radiology we had modalities from Philips, Siemens, and Bruker the interfacing was one of the most difficult parts of the implementation.

When the PACS was planned a routinely used radiological information system managing all administrative data, the documentation, and report generation was already installed in the department of radiology. The PACS is considered to be an add-on to the RIS driven by the RIS as the master. Both the RIS and the PACS are developed and implemented by the company prompt! a spin-off of Philips Medical Systems[1].

THE CONFIGURATION OF THE PACS

Modalities

In the current state the PACS integrates 3 computed radiography systems, 3 magnetic resonance imaging machines (MRI), 3 computed tomography machines, and a scanner for radiological films as modalities (see Fig. 1)[2]. The scanner is used to get images provided by external sources into the PACS. But this is only used for selected images.

Viewing Stations

Several different types of viewing stations produced by prompt! (RVS and DWS), Philips Medical Systems (EasyVision) or Siemens (MagicView and Prominence) are connected to the PACS. The result viewing station (RVS) and the diagnostic workstation (DWS) differ only in the monitors. The DWS has high luminescence monitors with a 2k by 2k resolution. In addition to these monitors it is also possible to have access to the images and reports stored in the PACS using standard PCs with a DICOM compatible viewing application. Such a solution is desired for use with PCs already installed on the ward, where images and results are always displayed together and the quality of the image is sufficient to illustrate the result even when the monitor is not sufficient for diagnostic work. The PCs all have access to the hospitals FDDI fiber-bases backbone

A different type of workstation is the demonstration PC. It is connected to a video beamer displaying the images. This workstation is used in the daily demonstration of surgical patients replacing the alternator. The advantage is that the images now are visible even at a greater distance so that the demonstration can be followed by more participants.

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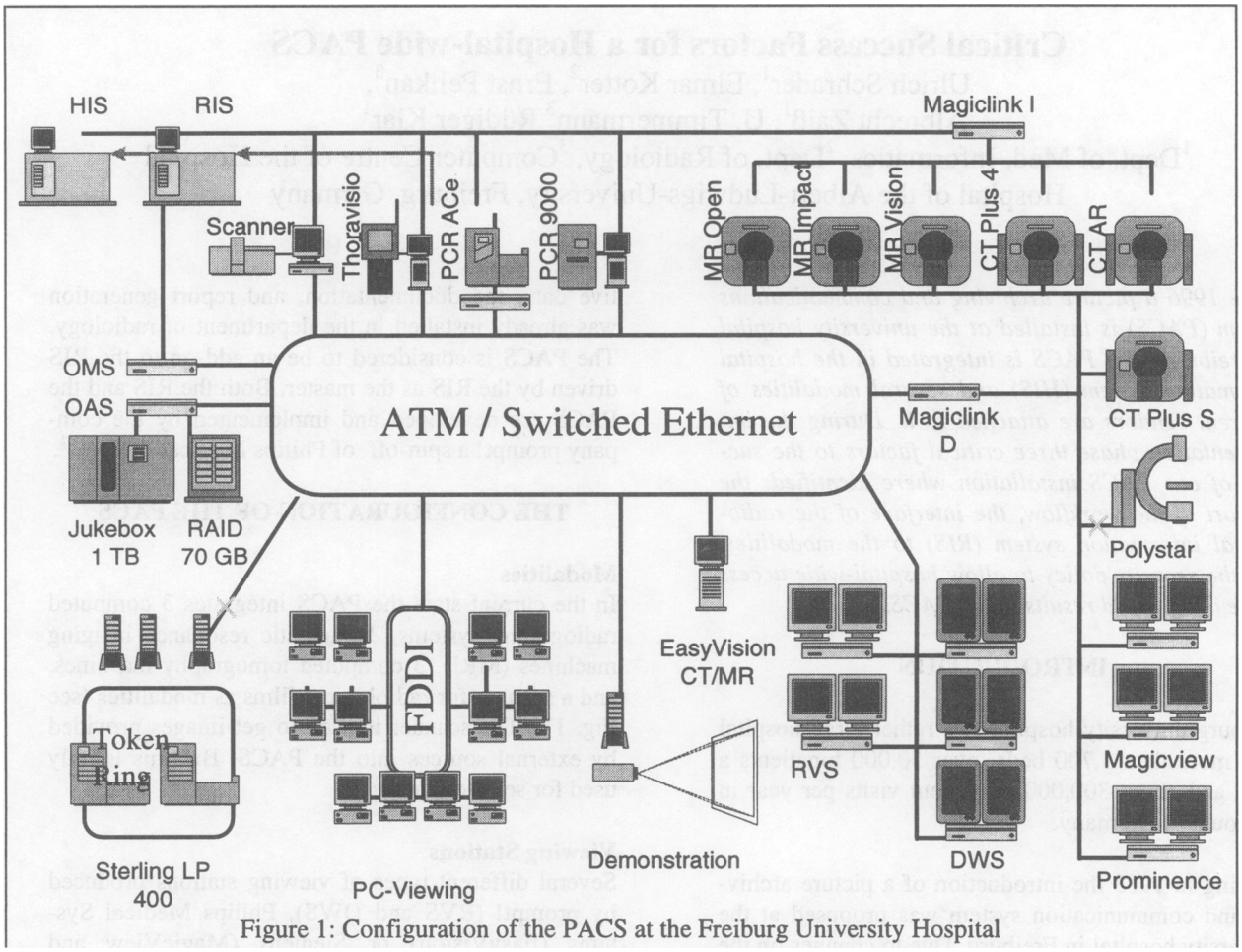

Figure 1: Configuration of the PACS at the Freiburg University Hospital

DICOM 3.0 Interface

While in the past most modalities offered only proprietory interfaces to export their images, every interface of a modality to the PACS had to be individually designed and implemented. The emergence of the ACR-NEMA standard eased the task somehow but still the different flavours of the implementations of the standard made it necessary to individually configure every modality-PACS interface. Some manufacturers still did not implement an ACR-NEMA interface for their modalities using the different flavours or missing functions of the standard as an argument.

The availability of the DICOM 3.0[3] standard as the successor of the ACR-NEMA standard changed this dramatically. The DICOM storage service class now specifies the transfer operations common to all types of images. In the past the manufacturers were not very communicative about the specifications of their proprietory interfaces. But DICOM requires that every implementation claiming conformance to the standard has to provide a conformance statement most differences about the implementations between manufacturers could be quickly resolved. Since compatibility to the DICOM standard and thus connectivity became a vendor's argument, manufacturers had to offer a conformance statement thus making the specifications of their interface publicly available,

In order to make use of this emerging standard the archive of the PACS was changed to store DICOM objects and to additionally provide the DICOM query/retrieve service class. This makes it possible for any DICOM 3.0 compatible application to search the archive for patient records, individual studies, or images. Once the images are selected they can then be retrieved or requested from the archive.

Using the above mentioned service classes not only the modalities of different vendors were connected to the PACS archive but also different viewing stations could be integrated. Most problems arising in the integration process were caused by the sometimes immature implementations of the DICOM 3.0 inter-

face still incorporating misunderstandings of the standard. Mostly they were rather quickly discovered and could be resolved rather quickly. In some cases still a workaround was necessary.

RIS-Modality Interface

If a modality sends a DICOM object to the PACS the archive must be able to extract patient demographic data as well as data uniquely describing the study so

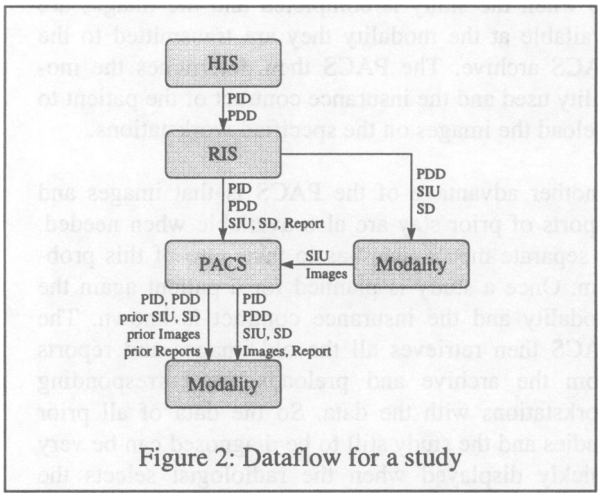

Figure 2: Dataflow for a study

that the object can be indexed correctly in the database. If the information is not available the object can be stored in the archive but must be manually indexed thus creating unnecessary overhead and delay in the diagnosis of the images. Although the RIS-modality interface is sometimes not considered to be part of a PACS it is of elementary importance for a routinely used PACS.

In general once a study for a patient is planned in the RIS the patients demographic data and the study data are transmitted to the modality. There the data are displayed in the modality's worklist until the patient arrives. Since the modalities had not implemented the DICOM worklist service class at that time each modality had to be interfaced individually to the RIS using proprietary interfaces of the modalities.

Archive

Considering the importance of the DICOM 3.0 standard we decided to have our archive changed completely so that it now stores only DICOM objects and is offering the necessary DICOM service classes like storage and query/retrieve. An important feature of the archive is the complete separation of the object management server (OMS) and the object archiving server (OAS). This will allow us to have in the future several archiving nodes using different media while the object describing information is still handled by the same OMS.. So it is possible to add to the PACS cheaper, faster archives or archives with a higher storage capacity as the need and technology arises. Currently we are using a 1 Terabyte Kodak Jukebox as the long term archive. Due to the high data volume produced by the modalities it will be necessary in the near future to expand the archive. New media available like the digital versatile disk (DVD) will have to be considered as possibly more cost effective alternatives.

In addition to the long term archive a 70 GB RAID system is used for short-term storage. The RAID system has two functions:

1. to speed up the access to images newly created by the modalities

2. to be used as a faster access buffer for old images again already archived on optical disks with a high probability of being accessed again.

The RAID system also stores newly created images before they are send to the long-term storage on the optical disks in the jukebox. It is desired to collect as many data for one patient as possible before they are written to the optical disk. This will minimise the number of disks necessary to retrieve the data for this patient at a later time thus speeding up the access to the long-term storage. In the same way images that might be retrieved in the future are buffered in the RAID system as well to have a faster access to them.

SUPPORTING THE WORKFLOW

For a PACS to be accepted in routine work it is essential that it enhances the daily workflow. Although the time required to retrieve an image from the optical disk storage of the archive is short compared to the time required to find the image in a film-based archive it is still very long if it will be retrieved when the demand arises and the user has to wait in front of the screen. Thus prefetching or preloading mechanisms have been proposed.[5] To implement these mechanisms we closely followed the workflow in the department of radiology. This enabled us to find rather simple algorithms for preloading of images and reports. Since the RIS is the master of the PACS it triggers all necessary actions.

Dataflow

To illustrate the dataflow we will follow a patient through all stages in the department. (Fig. 2) Once a

patient arrives in the radiology department his demographic data are retrieved in the RIS. In case the data are not available because this is his first time in the department the RIS tries to retrieve the patient demographic data (PDD) from the master patient index (MPI) of the HIS. If he has not been admitted there before he will now be admitted in the HIS. Then his data are automatically retrieved by the RIS. At the Freiburg university hospital all patients are assigned for their live a unique patient identification (PID). Upon readmittance great care is being taken that the patient is correctly identified and his old PID is reassigned to him. This is important since all clinical data for a patient are linked together using the PID thus creating the medical record of this patient.

Next the study is planned and the defining data of the study (SD) and the study instance unique identifier (SIU) are transmitted together with the patients data to the PACS and the modality. Now the patient appears on the modality's worklist. So when the patient arrives he only has to be selected from the list. Once the study has been performed the image data together with the SIU are transmitted to the PACS. Since the patient data, the PID, the study date, and the SIU are already transmitted to the PACS by the RIS the images can be easily linked to the patient and the study.

Later when the report is generated in the RIS it is transmitted from the RIS to the PACS again using the SIU as the identify link. It is very important that the images are stored together with the reports in the PACS so that they can be displayed as a unit to clinicians outside the department of radiology using low-cost PC workstations available on the wards.

Workflow

In order to have the patient data and the images already loaded at the workstation trigger events are necessary. Since it would consume to many resources at the workstation to load the data and images of all active patients at every workstation mechanisms have to be found to load the data only at the workstations where they will be needed with the highest probability.

It turned out that we only need two criteria for the selection at the present time.

- the modality where the images were generated
- the type of insurance of the patient

The first criteria reflects the organisation of the radiology department. Radiologists working at a specific modality are using also workstations assigned to them. They are generally located close to the modality.

The second criteria results from the German health insurance system. Depending on the contract you have the right to choose the physician doing the diagnosis. They also need the patients data and the images.

So when the study is completed and the images are available at the modality they are transmitted to the PACS archive. The PACS then determines the modality used and the insurance contract of the patient to preload the images on the specified workstations.

Another advantage of the PACS is that images and reports of prior stay are also available when needed. A separate mechanism has to take care of this problem. Once a study is planned for a patient again the modality and the insurance contract is known. The PACS then retrieves all the old images and reports from the archive and preloads the corresponding workstations with the data. So the data of all prior studies and the study still to be diagnosed can be very quickly displayed when the radiologist selects the patient.

In the current phase all images and reports are being selected. This can cause the transmission of unnecessary data for example if prior studies where about a broken limb and the current study is mainly concerned with the skull. Since no long patient histories are currently present in the PACS this does not create a problem yet. But research has to be done to determine a filter to preload only relevant images. This has not been done so far.

SECURITY POLICY

Most smaller PACS are limited to the radiology department. Here the access to the patient data and images can be restricted using standard mechanisms like hierarchies or user groups. They reflect the mostly static organisational structure of the department. If the access control is not implemented in the PACS itself standards like e.g. directory service offered by X.500 could be used. A different method of access control must be used if external access to the data in the PACS should be possible for every clinician in the hospital.[6] Here the security policy of the hospital has to be taken into account. In principle a security policy defines rules about *who* may do *what and when* with *which object*. The security policy of

our hospital for external access can be defined using four basic rules:

1. All external access is restricted to read-only access.
2. All images and findings that are the result of an order are always visible for the placer of the order.
3. The department that is directly taking care of the patient has *temporary* access to all images and findings. This access is denied after the patient's care is completed.
4. Departments that are indirectly involved in the diagnostic or the treatment process of a patient as defined as being the filler of orders for this patient also have *temporary* access.

While the first two rules can easily be resolved by the PACS itself the last two rules can only be solved by the HIS since only the HIS can determine who is taking care of a patient at any time. The only problem in solving the first two rules is that the PACS would have to handle all clinicians in the hospital in our case this would mean about 3000 possible users. Since the problem with the last two rules arises always with access to all departmental data it does not make sense to solve this problem individually but rather to create a central authorisation service. As described in fig. 3 the PACS would contact this service once an external clinician tries to get access to data denied by the first two rules. The authorisation service then checks the HIS to see whether this clinician is currently taking care of the patient and grants the rights if appropriate.

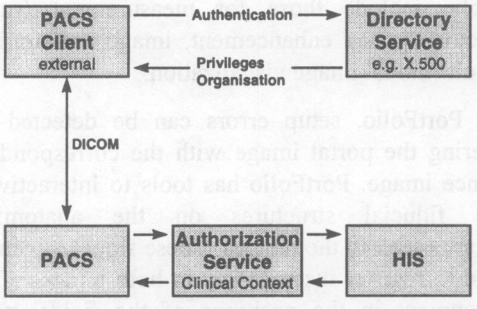

Figure 3: Concept for the implementation of the security policy

This service not only can be used by the PACS but also by other department systems to allow automated access to their data.

CONCLUSION

Build upon the experiences from the large-scale PACS at Freiburg university hospital important criteria for successful routine use can be identified: 1. the workflow within the radiology department must be supported by preloading of the patients data and images, 2. the RIS-modality interface must be realised, and 3. the access to the PACS by any clinician in the hospital can best be automated using a central access server.

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